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THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SOME ASPECTS OF MODERN PETROLOGY[1]

IN accordance with the custom which permits the occupant of this chair to open the proceedings with observations on some selected subject, I wish to invite your attention to certain points concerning the genetic relations of igneous rocks. The considerations which I shall have to lay before you will be in some measure tentative and incomplete; and indeed, apart from personal shortcomings, this character must necessarily attach to any discussion of the subject which I have chosen. For petrology is at the present time in a state of transition—the transition, namely, from a merely descriptive to an inductive science—and at such a time wide differences of opinion are inevitable. If I should seem to do less than justice to some views which I do not share, I hope this fault will be attributed to the limitations of time and space, not to any intention of abusing the brief authority with which I find myself invested.

The application of microscopical and special optical methods, initiated some fifty years ago by Dr. Sorby, gave a powerful impetus to the study of the mineral constitution and minute structure of rocks, and has largely determined the course of petrological research since that epoch. For Sorby himself observation was a means to an end. His interest was in the conclusions which he was thus enabled to reach relative to the conditions under which the rocks were formed, and his con-

[1] Address of the president to the Geological Section. Portsmouth, 1911.

tributions to this problem will always rank among the classics of geology. The great majority of his followers, however, have been content to record and compare the results of observation without pushing their inquiries farther; and indeed the name "petrography," often applied to this line of research, correctly denotes its purely descriptive nature. A very large body of facts has now been brought together, and may be found, collated and systematized by a master-hand, in the monumental work of Rosenbusch. Beyond their intrinsic interest, the results thus placed on record must be of the highest value as furnishing one of the bases upon which may eventually be erected a coherent science of igneous rocks and igneous activity.

In earnest of this promise, recent years have witnessed a very marked revival of interest in what we must call at present the more speculative aspects of petrology. This manifests itself on the side of the petrographer in a growing disposition to seek a rational interpretation of his observations in the light of known physical principles, and on the side of the field geologist in a more constant regard for the distribution, mutual associations, and mode of occurrence of igneous rocks. I will add, as another hopeful sign of the times, a decided *rapprochement* between the laboratory and the field, too often treated in practise as distinct departments.

As regards the former, the movement which I have noticed is merely a return to the standpoint of Sorby, the father of modern petrology. It is true indeed that, before his time, the problem of the origin of igneous rocks had engaged the ingenuity of Scrope and Darwin, of Bunsen and Durocher, and many others; and the bold speculations of the heroic days of geology have justly exercised a lasting influence. The petrologist of to-day, however, has at his command a much ampler range of information than was possessed by his predecessors. In addition to the rich store of petrographical data already mentioned, he can press into service, on the one hand, the results of physical chemistry and, on the other, much additional knowledge which has been gathered concerning the structure of the earth's crust and the distribution of various rock-types, both in space and in time. Either of these branches of the subject would furnish material for a much longer address than my assurance could venture or your complacence would endure. I have chosen the geographical aspect of petrology; but, before proceeding to this, I will say a few words concerning the experimental side.

DATA FROM THE EXPERIMENTAL SIDE

That the modern developments of physical chemistry, starting from the phase rule of Willard Gibbs, must in theory furnish all that is necessary to elucidate the crystallization of igneous rock-magmas, has long been perceived by some petrologists. This recognition is in itself an advance. Natural rock-magmas, however, are far more complex solutions than those which chemists have employed in working out their laws, and the problem in its entirety is of a kind almost to daunt inquiry. Despite the courageous attempt made by Professor Vogt, whose enthusiastic lead has done so much to inspire interest in the subject, it seems clear that the application of the laws of chemistry to the particular class of cases with which the petrologist is concerned demands as a prerequisite a large amount of experimental work in the laboratory. The high melting-points of the rock-forming minerals, their extreme viscosity, and other specific properties render such work extremely difficult and

laborious. That most of the practical difficulties have now been overcome is due in the first place to Dr. A. L. Day and his colleagues of the Geophysical Laboratory at Washington, who have thus opened out what is virtually a new field of investigation. The methods of high temperature measurement have been perfected and the thermometric scale standardized up to 1550° C., thus embracing the whole range of rock-formation. Calorimetric measurements have been so far improved that it is now possible, for instance, to determine specific heats, even in the highest part of this range, with an accuracy ten times greater than has hitherto been usual at ordinary temperatures. Incidentally there has been, in the hands of Mr. F. E. Wright, a notable enlargement of the scope of ordinary petrographical methods, since it has been found necessary to devise special means of measuring with precision the crystallographic and optical constants of very minute crystals.

The American chemists have already determined the temperature-range of stability of numerous rock-forming minerals. Beginning with the simpler cases and working always with chemically pure material, they have established quantitatively the mutual relations of the various possible forms in a number of two-component systems and in one of three components. So far as these instances go, the mutual lowering of melting-points in a silicate-magma is now a matter of precise measurement, and it is no longer inferred, but demonstrated, that the order of crystallization of the minerals depends upon their relative proportions in the magma. The perfect isomorphism of the plagioclose felspars has been finally established, and a certain degree of solid solution between quite different minerals has furnished the explanation of some apparent anomalies, such, for instance, as the variable composition of the mineral pyrrhotite. As a single illustration of how these investigations in the laboratory provide the working petrologist with new instruments of research, I will cite the conception of a geological temperature-scale, the fixed points on which are given by the temperature-limits of stability of various minerals. It is often possible, for example, to ascertain whether quartz in a given rock has crystallized above or below 575° C., this being the inversion-point between the α- and β-forms of the mineral. At about 800° there is another inversion-point, above which quartz is no longer stable, but gives place to cristobalite. In like manner we know that wollastonite in a rock must have crystallized below 1190°, pyrites below 450°, and so for other cases. We may confidently hope that, with the aid of such data, we shall soon be enabled by simple inspection, to lay down in degrees the temperature-range of crystallization of a given igneous rock.

There are now several laboratories where high-temperature research, of the rigorous order indicated, is being carried out; but the work is peculiarly arduous and results come slowly. Some branches of the inquiry, notably those involving high pressures, and again the investigation of systems into which volatile components enter, are as yet virtually untouched. For these reasons it would be premature to hazard at this stage any more detailed forecast of the services to be rendered to petrology by synthetic experiment. I will accordingly leave this attractive subject and pass on from the laboratory to the field.

GEOGRAPHICAL DISTRIBUTION OF IGNEOUS ROCKS

Here the existing situation is very different. Instead of following out definite lines already laid down, we are concerned

in reducing to order a great mass of discrete facts drawn from many sources. The facts which enter into consideration are those touching the distribution of various igneous rocks in time, in space and in environment, including their relation to tectonic features; the mutual association of different rock-types and any indications of law in the order of their intrusion or extrusion; and, in short, all observable relations which may be presumed to have a genetic significance. The digestion of this mass of data has already led to certain generalizations, some of which are accepted by almost all petrologists, while others must be regarded as still on their trial.

Of the former kind is the conception of petrographical provinces, which was put forward by Professor Judd twenty-five years ago, and has exercised a profound influence on the trend of petrological speculation. It is now well established that we can recognize more or less clearly defined tracts, within which the igneous rocks, belonging to a given period of igneous activity, present a certain community of petrographical characters, traceable through all their diversity or at least obscured only in some of the more extreme members of the assemblage. Further, that a province possessing an individuality of this kind may differ widely in this respect from a neighboring province of like date; while, on the other hand, a striking similarity may exist between provinces widely separated in situation or in age. It is natural to attribute community of chemical and mineralogical characters among associated rocks to community of origin. The simplest hypothesis is that which supposes all the igneous rocks of a given province to be derived by processes of differentiation from a single parent-magma. This may be conceived, for the sake of simplicity, as initially homogenous, though doubtless some of the causes which contribute to promote heterogeneity were operative from the earliest stage. Granted this hypothesis, it follows that the points of resemblance among the rocks of a province will indicate the nature of the common parent-magma, while the points of diversity will throw light on the causes of differentiation. The observed sequence in time of the various associated rock-types will also have an evident significance, especially if, as there are good reasons for believing, differentiation in igneous rock-magmas is largely bound up with progressive crystallization. Those petrologists, on the other hand, who attach importance to the absorption or "assimilation" of solid rock-matter by molten magmas, are bound to consider both the nature of the chemical variation and the local distribution of the different types with constant reference to the composition of the country-rocks. The balance of opinion, and I think of argument, would assign the variation, at least in the main, to differentiation; and there are well-known principles, chemical and mechanical, which theoretically must operate to produce a diversity of ultimate products from a magma originally uniform. How far these principles are in practise adequate to the demands which have been made on them is a question not to be finally resolved without quantitative knowledge which is still a desideratum. Experiment may in time come to our aid. My design to-day is rather to offer some remarks upon a distinct, though allied, problem—viz., that presented by the petrographical provinces themselves.

The geographical distribution of different kinds of igneous rocks long ago engaged the attention of Humboldt, Boué, and other geologists, and the subject has always possessed a certain interest in view of the association of most metalliferous de-

posits with igneous rocks. It has, however, acquired a new importance in recent years in connection with questions of petrogenesis which are still under discussion. The problem is, in brief, to account for the existence of petrographical provinces and for the observed facts relative to their distribution. One theory, advocated especially by Dr. G. F. Becker, invokes primeval differences in composition between different parts of the globe, which have persisted throughout geological time. It involves the hypothesis that igneous rock-magmas result from the refusion of pre-existing rocks within a limited area. Indeed Becker discards altogether the doctrine of differentiation, and conceives the varied assemblage of rocks in a given province as produced by admixture from a certain number of primitive types. These, he says, should be recognizable by their wide distribution and constant character. It is clear, however, that, on the hypothesis of admixture, the primitive types must be those of extreme composition. These are, in fact, always the rarest and the most variable, pointing not to admixture, but to differentiation as the cause of the diversity. A theory which attributes the special characteristics of petrographical provinces to permanent heterogeneity in the composition of the globe is difficult to reconcile with the small extent and sharp definition of some strongly characterized provinces, such as that of Assynt or of the Bohemian Mittelgebirge. A more fatal objection is that petrographical provinces are not in fact permanent. A good illustration is afforded by the midland valley of Scotland, an area our knowledge of which has been much enlarged by the recent work of the Geological Survey. It was the theater of igneous activity in Lower Old Red Sandstone times and again in the Carboniferous, but, in respect of mineralogical and chemical composition, the two suites of rocks present a striking contrast. The Old Red Sandstone lavas are mostly andesites, though ranging from basalts, on the one hand, to rhyolites, on the other, and the associated intrusions are mainly of diorite, quartz diorite and granite, with porphyrites and other dyke-rocks. In the Carboniferous, on the other hand, we find porphyritic basalts, mugearites and trachytes (including phonolitic types), with picrites, teschenites, monchiquites, orthophyres and other allied rocks. It would be possible to cite many other cases illustrating the same point.

THE ALKALINE AND CALCIC BRANCHES

The two Scottish suites of Upper Paleozoic rocks just mentioned fall into opposite categories with reference to what is now becoming recognized as the most fundamental distinction to be made among igneous rocks. The earlier set is typical of the andesitic division and the later of the tephritic; or, using other equivalent names, the one belongs to the calcic (or "alkali-calcic") branch and the other to the alkaline. I will adopt the latter terminology as being generally familiar to petrologists; but the characteristics of the two branches, which are too well known to need recapitulation here, are more clearly definable in mineralogical than in chemical language. This two-fold division of igneous rocks is, of course, in no wise a final or exhaustive treatment of the subject; but as a first step towards a natural or genetic classification it seems to be established beyond question. No third branch in any degree comparable with the two and distinct from them has been proposed. The charnockites and their allies represent but a single rock-series, and Rosenbusch has not made clear his reasons for separating them from the calcic rocks.

The "spilitic" suite of Dewey and Flett is made to embrace a somewhat miscellaneous collection of types, and any close genetic relationship among them can scarcely be considered as proved. It is perhaps permissible to suggest that, *e. g.*, the quartz-diabases are, here as in Scotland, quite distinct in their affinities from the types rich in soda. These latter, constituting the bulk of the proposed suite, would seem to belong quite naturally to the alkaline branch, the question of the magmatic or solfataric origin of the albite being in this connection immaterial.

A given petrographical province is either of calcic or of alkaline facies, typical members of the two branches not being found together. The apparent exceptions are, I think, not such as to modify very seriously the general rule. Mr. Thomas, in describing an interesting suite of rocks from western Pembrokeshire, recognizes the alkaline affinities of most of them, but assigns some of the more basic types to the opposite branch. In a very varied assemblage we not infrequently meet with a few extreme types which, occurring in a calcic province, recall the characters of alkaline rocks, or conversely. Such anomalies have been pointed out by Daly, Whitman Cross, and others. They are found among the later derived types, referable to prolonged or repeated differentiation, and they are to be expected especially where the initial magma was not very strongly characterized as either calcic or alkaline.

Having regard to the known exposures of igneous rocks over the existing land-surface of the globe, it seems that there is a very decided preponderance of the calcic over the alkaline branch. This, as we shall see, is probably a fact of real significance, but it is nevertheless noticeable that increasing knowledge tends partly to redress the balance. In our own country, in addition to the Scottish Carboniferous rocks and those probably of Ordovician age in Pembrokeshire, we have the remarkable Lower Paleozoic intrusions of Assynt, in Sutherland, of strongly alkaline character, as described by Dr. Teall and more recently by Dr. Shand; while Dr. Flett has recognized alkaline rocks of more than one age in Cornwall and Devon, and Mr. Tyrrell is engaged in studying another interesting province, of Permian Age, in Ayrshire.

That the distinction between the alkaline and the calcic rocks embodies some principle of real and fundamental significance becomes very apparent when we look at the geographical distribution of the two branches. Taking what the German petrographers call the "younger" igneous rocks, *i. e.*, those belonging to the latest system of igneous activity, we find it possible to map out the active parts of the earth's crust into great continuous regions of alkaline rocks on the one hand and of calcic on the other. An alkaline region comprises numerous petrographical provinces, which may differ notably from one another, but agree in being all of alkaline facies. In like manner a common calcic facies unites other provinces, which collectively make up a continuous calcic region. Concerning the igneous rocks of earlier periods our knowledge is less complete, but, so far as it goes, it points to the same general conclusions.

These considerations enable us to simplify at the outset the problem before us. If we would seek the meaning and origin of petrographical provinces, we must inquire in the first place how igneous rocks, as a whole, come to group themselves under two great categories, which, at any one period of igneous activity, are found in separate regions of the earth's crust. The

fact that a given district may form part of a calcic province at one period and of an alkaline one at another, precludes the hypothesis that the composition of igneous rocks depends in any degree upon peculiarities inherent from the beginning in the subjacent crust. The same objection applies with scarcely less force to various conflicting suggestions based on an assumed absorption or "assimilation" of sedimentary rocks by igneous magmas. Thus Jensen supposes the alkaline rocks to be derived by the assimilation or fusion of alkaline sediments at great depths. Daly propounds the more elaborate, and on a first view paradoxical, theory that alkaline have been derived from calcic magmas as a consequence of the absorption of limestone. These geologists agree in regarding the alkaline rocks as relatively unimportant in their actual development and in some sense abnormal in their origin. For Suess, on the other hand, it is the calcic rocks which owe their distinctive characters to an absorption of sedimentary material, enriching the magma in lime and magnesia. Apart from difficulties of the physical and chemical kind, all such theories fail to satisfy, in that they ignore the separation of the two branches of igneous rocks in different regions of the globe, each of which includes sediments of every kind. What then is the real significance of this regional separation? The obvious way of approaching the question is to inquire first whether the alkaline and calcic regions of the globe present any notable differences of a kind other than petrographical.

RELATION BETWEEN TECTONIC AND PETROGRAPHICAL FACIES

The close connection between igneous activity and displacements of the earth's crust has been traced by Suess, Lossen, Bertrand, de Lapparent and others, and is a fact sufficiently well recognized. We have here indeed two different ways of relieving unequal stresses in the crust, and it is not surprising that they show a broad general coincidence both in space and in time. We can, however, go farther. Not only the distribution of igneous rocks in general, but the distribution of different kinds of rocks is seen to stand in unmistakable relation to the leading tectonic features of the globe. It is very noticeable that petrographical provinces, and in particular provinces belonging to opposite branches, are often divided by important orographic lines. This is illustrated by the Cordilleran chain in both North and South America, and again by some of the principal arcs of the Alpine system in Europe. If now we examine the actual distribution more closely, in the light of Suess's analysis of the continents and oceanic basins, we perceive another relation still more significant. It is that, as regards the younger igneous rocks, the main alkaline and calcic regions correspond with the areas characterized by the Atlantic and Pacific types of coast-line, respectively. I briefly drew attention to this correspondence in 1896, and a few years later Professor Becke, of Vienna, arrived independently at the same generalization. Recalling the two classes of crust-movements discriminated by Suess, he says it appears that the alkaline rocks are typically associated with subsidence due to radial contraction of the globe, and the calcic rocks with folding due to lateral compression. The greater part of Becke's memoir is devoted to a comparison of the two branches in respect of chemical composition; but here, I think, he has been misled by taking as representative of the whole alkaline "*Sippe*" or tribe the rocks of one small and peculiar province, that of the Bohemian Mittelgebirge. Some petrologists have followed Becke in adopting the

terms Atlantic and Pacific as names, or at least synonyms, for the two branches of igneous rocks. Others, perhaps with some justice, deprecate the use of the same terms in a petrographical as well as a tectonic sense, so long as the implied relationship is still a matter of discussion.

I would point out in passing that the association of the alkaline rocks with areas of subsidence helps to explain the relatively small part which they play in the visible portion of the earth's surface. We may not unreasonably conjecture, for instance, that the volcanic islands scattered sparingly over the face of the Atlantic Ocean, from the Azores to Tristan d'Acunha, are merely fragments of a very extensive tract of alkaline rocks now submerged.

The generalization associated with the name of Becke, in so far as it may ultimately commend itself to general acceptance, must have an important bearing on the problem of the origin of petrographical differences. The time is not ripe for any dogmatic pronouncement, but I will venture to indicate briefly the general trend of the inferences to be drawn. It seems clear that only a trivial effect at most can be allowed to original and permanent heterogeneity of the earth's crust, or to such accidents as the absorption by an igneous magma of a limited amount of the country-rock. The division between alkaline and calcic regions, and the separation of distinct provinces within such regions, point rather to the same general cause which, at a later stage, produced the diversity of rock-types within a single province, that is to magmatic differentiation. Here, however, the differentiation postulated must be on a very wide scale, and must take effect in the horizontal direction. Its close connection with crust-movements clearly indicates differential stress as an essential element in the process. The actual mechanism can be at present only a matter of speculation, but I think the clue will be found in such observations as those of Mr. Barrow on the pegmatites of the Scottish Highlands. Conceive an extensive tract to be underlain by a zone which is neither solid nor liquid, but composed of crystals with an interstitial fluid magma. If this be subjected to different pressures in different parts of its horizontal extent, its uniformity will necessarily be disturbed, the fluid portion being squeezed out at places of higher pressure and driven to places of lower pressure. The precise nature of the differentiation thus set up will depend on the relative compositions of the crystalline and fluid portions, and the subject could not be very profitably discussed without fuller knowledge concerning the order of crystallization in rock-magmas. Whether or not the explanation be ultimately found in this direction, the relation between the two tectonic types and the two branches of igneous rocks must, I think, find a place in the final solution of the problem.

I intimated at the outset that my remarks would not be confined to matters already settled and indisputable. It will be easily understood that some statements which I have made, for the sake of clearness, without qualification are subject to exceptions, and exceptions have, indeed, been urged by critics whose opinions are entitled to respect. The most uncompromising of these critics, Dr. Whitman Cross, has laid it down that: "Only generalizations without known exceptions in experience can be applied to the construction of a system that may be called natural." I hold, on the contrary, that such a science as geology can be advanced only by the inductive method, which implies provisional hypotheses and successive approximations

to the truth. A generalization which brings together a mass of scattered observations, and endows them with meaning, is not invalidated by the discovery of exceptions. These merely prove that it is not a final expression of the whole truth, and may point the way to its revision and correction.

Take, for instance, our provisional law of the distribution of the two branches of igneous rocks in defined regions. It has been objected that leucitic lavas, having therefore very decided alkaline or Atlantic affinities, are known at several places within the limits of the main Pacific region, where they are associated with andesitic and other calcic rocks. Now, the only area for which we have anything like full information is the island of Java. Here, according to Verbeek and Fennema, the great plateau-lavas of Tertiary age are exclusively of andesitic types, and the same is true of the long chain of 116 volcanic centers, which represent the later revival of activity. As against this record there are five volcanoes, long extinct, which at one stage erupted leucitic lavas. Whether we suppose these to be aberrant derivatives from an andesitic magma, or, much more probably, an incursion from the neighboring alkaline region, it seems reasonable to regard these very exceptional occurrences as of the second order of importance, and to set them aside in a first attempt to reduce the facts to order.

The discovery of various alkaline rocks on Hawaii, Samoa, Raratonga, Tahiti and other islands in the midst of the Pacific Ocean raises, I think, a different question. So far as is known, these rocks are not found in close association with characteristic calcic types. Suess's masterly discussion of all the geographical and hydrographical data hitherto obtained makes it clear that an Atlantic as well as a Pacific element of structure enters into some parts of the Pacific basin. In certain areas, such as the Galapagos Archipelago, the coming in of the Atlantic régime is quite clearly reflected in an alkaline facies of the igneous rocks, and such exceptions are therefore of the kind which go to prove the rule. Both Max Weber and Lacroix have expressed the opinion that the andesitic branch of rocks is characteristic of the border of the great Pacific basin rather than the interior. It is possible that further knowledge may justify this conclusion, and still only confirm the relation which is claimed between the two tectonic types and the two petrographical facies. Meanwhile we find clear evidence elsewhere that vertical subsidence and lateral thrust have sometimes occurred in the same region or in the same petrographical province; nor need we go far from home to learn that the complexity of structure thus implied is accompanied by a corresponding peculiarity of petrographical facies.

THE NORTH BRITISH TERTIARY PROVINCE

In order to illustrate this point in a concrete instance, I will discuss very briefly a single petrographical province, viz., that which occupied the northern part of Britain in early Tertiary times. Professor Judd has regarded this as forming part of a larger "Brito-Icelandic province"; but, while recognizing many affinities between our rocks and those of higher latitudes, I think that the North British area possesses enough individuality to be more properly treated as a distinct unit. The record of igneous action here is exceptionally complete and well displayed. Our knowledge of it is derived in the first place from Professor Zirkel, Sir Archibald Geikie and Professor Judd, and more recently from the detailed work carried out by the Geological Survey of Scotland. This latter is,

as regards the Isle of Mull, still in progress, and will doubtless when completed throw additional light on some questions still obscure.

The province includes all western and southern Scotland, with the northern part of Ireland, and extends southward as far as Anglesey and Yorkshire, but the chief theater of igneous activity was the sunken and faulted tract of the Inner Hebrides, between the mainland of Scotland, on the one hand, and the Archæan *massif* of the Outer Isles, on the other. It is here that the volcanic accumulations attain their greatest thickness, and here, closely set along a N.–S. line, are the plutonic centers of Skye, Rum, Ardnamurchan and Mull. Farther south are the volcanic plateau of Antrim and the neighboring plutonic centers of the Mourne Mountains and Carlingford, while the two centers of Arran and that of Ailsa lie on a parallel line only a little farther east. In addition it is clear that igneous activity extended westward over a tract now submerged under the Atlantic, and here too plutonic centers were not wanting. One is exposed in St. Kilda, 50 miles west of the Outer Hebrides, and another has been inferred by Professor Cole from a study of the stones dredged on the Porcupine Bank, 150 miles west of Ireland.

The connection of igneous action in this province with the subsidence of faulted blocks of country is too plain to be missed; and so far, excepting the tendency to a definite alignment of the foci of activity, we seem to be dealing with a typical example of the Atlantic régime. The actual tectonic relations are, however, of a more complex kind, and undoubtedly involve the element of lateral thrust as well as vertical subsidence. This is more particularly in the neighborhood of those special centers which were marked at one stage by plutonic intrusions. The evidence is seen in sharp anticlinal folding; sometimes also in crush-brecciation along quasi-horizontal bands and (in Rum) contemporaneous gneissic structure in the plutonic masses themselves. The disturbances in Mull, as described by Mr. Bailey, are especially interesting. The whole eastern coast-line of the island is determined by a system of concentric curved axes of folding, affecting all the rocks up to the Tertiary basalts, which are in places tilted almost vertically. The curved axes are disposed with reference to the plutonic center of the island, and a somewhat similar arrangement is found on the east side of the Skye center. All these facts go to show that in the district surrounding any one of the special centers there was developed a complex system of stresses, which found relief partly in igneous action, partly in displacements of the solid rocks. Nor were the effects confined to the plutonic phase. At a later epoch the influence of these local stresses is sometimes indicated by the diversion of the very numerous dykes from their normal northwesterly direction to a radial arrangement about the special centers, as is seen partly in Skye and more strikingly in Rum. There are also local groups of dykes developed only in these districts, and these again sometimes have a radial arrangement. More remarkable are the groups of inclined sheets which are found about the same centers, usually intersecting the plutonic rocks and a small fringing belt, and constantly dipping inwards. Such sheets occur in immense numbers in the gabbro mountains of Skye and Mull, and they are to be recognized also in Rum and Ardnamurchan.

It is plain then that this province exemplifies at once the two tectonic types distinguished by Suess. There has been a general subsidence, affecting the area as a

whole but not all parts equally, and with this we must connect those groups of igneous rocks which have a wide distribution throughout the province. But there have also been movements in the lateral sense, more strictly localized and more sharply accentuated, and to these belong evidently the plutonic rocks with various other groups which are their satellites. I have pointed out these facts elsewhere, but failed to follow out the logical conclusions on the petrographical side. Influenced by the strongly marked characters of the plutonic series, I assigned the North British Tertiary rocks, not without some misgivings, to the calcic or Pacific region. Suess, having regard probably to the broader tectonic features rather than to petrographical data, has included our area in the Atlantic region.

Concerning the calcic facies of the plutonic rocks there can be no question. They constitute a well-defined "rock-series," intruded in order of decreasing basicity, and ranging from ultrabasic to thoroughly acid. The ultrabasic rocks, as developed in Rum and Skye, have a lime-felspar as one of their chief components: there are no picrites (in the original sense of Tschermak) or other alkaline types. The eucrite group, found in Rum, Ardnamurchan and the Carlingford district, is also characterized by a felspar near anorthite. Gabbros are represented at nearly all the several centers, and in Arran they are accompanied by norites. The granites and granophyres fall into two sub-groups. The less acid is usually augitic, while the more acid, found in Arran, St. Kilda and the Mourne Mountains, carries hornblende and sometimes biotite.

This series is known in various provinces of Pacific facies. A peculiarity of it is that it is a broken series, types of mean acidity being absent. This has an interesting consequence. In many places a granite magma, invading rocks so different from itself as gabbro or eucrite, has caused energetic mutual reactions, and a set of hybrid rocks has been produced, which serves in a limited sense to fill the gap in the series.

The only known exceptions to the calcic facies of our Tertiary plutonic rocks are perhaps significant in that they occur near the northern and southern limits of the principal belt of activity. The massive gently inclined sheets of granite and granophyre which make up part of the southern end of Raasay consist largely of microperthite, and contain abundant riebeckite, a distinctively alkaline mineral known at only one spot in Skye. The microperthitic granites of Arran do not carry riebeckite, but it is found in the well-known rock of Ailsa Craig, farther south.

The local groups of minor intrusions—acid, basic and ultrabasic—related to the several plutonic centers have the same calcic facies as the plutonic rocks of which they are satellites. It appears, however, that they sometimes tend to a more alkaline composition towards the borders of their respective districts. Thus, the Skye granite is surrounded by a roughly oval area, within which are found numerous dykes and sills of felsite and granophyre, in general augitic; but on the fringe of the area these rocks give place to orthophyres, with biotite or hornblende, and to bostonites.

Turn now to the rocks of regional distribution. The most important are, of course, the basalt lavas. They are all felspar-basalts, but a very general feature is the filling of their numerous amygdaloidal cavities with zeolites, such as analcime, natrolite, chabazite and stilbite. These minerals are certainly not mere weathering-products. When I examined the ba-

salts of Skye and the Small Isles some years ago, I regarded the zeolites as solfataric products, formed at the expense of the felspar by the action of volcanic water, while the rocks were still at a somewhat high temperature. Subsequent reconsideration has led me to consider these minerals rather as primary constituents of the rock, crystallized directly from the final residual magma, which had become relatively enriched in water by the abstraction of the anhydrous minerals. Such was the conclusion reached by Mr. James Strachan for the Antrim basalts, and a study of examples from Mull and Skye has enabled me to confirm and extend his interesting observations. Analcime in particular is not always confined to the steam-cavities, but in some cases occurs interstitially in the rock, where it is certainly not derived from felspar, and, indeed, has all the appearance of a primary constituent. The augite of these analcime-bearing basalts has in thin slices a purplish tint, with sensible pleochroism. From these and other features it appears that this group of rocks reveals on examination decided, though not very strongly marked, alkaline affinities.

Volcanic rocks of other than basaltic composition are not largely developed. They include both rhyolites and trachytes, the former without very distinctive characters, but the latter falling naturally into the alkaline division. In describing formerly a group of rhyolites and trachytes on the northern border of the Cuillins, I connected it with the neighboring plutonic center, but I have since found other trachytes in Skye: there is a fine development exposed in the glen above Bracadale. From this, and from the situation of the Antrim rhyolites, I infer that these felspathic and acid lavas, though distributed sporadically, belong to the regional or Atlantic suite.

Consider next the wide-spread group of basic sills. The common non-porphyritic dolerite sills have, in most districts, little that is indicative of alkaline affinities, though chemical analyses show a rather noteworthy amount of soda. In the porphyritic dolerites this characteristic is much more apparent, and indeed these rocks are almost identical with the "Markle type" so largely represented among the alkaline rocks of the Scottish Carboniferous province. Mugearite, a type still richer in alkalies, is likewise common to the two provinces. As we approach the limits of the principal belt of activity, alkaline characteristics become well marked even in the common non-porphyritic dolerites. This is shown in Raasay and the northern part of Skye by the coming in of the purple pleochroic augite, while farther north, in the Shiant Isles, analcime enters and even, according to a record of Heddle, nepheline.[2] At the other extreme, in southern Arran, occur the analcime-dolerite sills of Clauchland and Dippin.

The regional basic dykes, which are mostly posterior in age to the sills, exhibit more variety of composition. Some with abundant porphyritic felspars resemble the Markle type of dolerite, and there are others of mugearitic nature, but these are only a minority. In Argyllshire there are basic dykes with purple pleochroic augite, and even some of camptonite and monchiquite; but these latter at least I should exclude as being probably of late Paleozoic age.[3] The undoubtedly Tertiary dykes, however, exhibit a variety which can be

[2] The dolerite here is intimately associated with ultra-basic rocks, as has been described by Judd.

[3] A like remark applies to the highly alkaline dykes of the Orkneys, which do not agree even in direction with the Tertiary suite.

explained only as the result of repeated differentiation. The distribution of some of the groups indicates the existence at this late stage of subsidiary centers of differentiation, distinct from the plutonic centers. Thus, trachyte dykes are found especially throughout a tract extending from the southwestern part of Skye through the middle of Argyllshire, while there is an isolated area of these dykes about Drynoch, on the opposite side of the Skye mountains. Here we have an evidently alkaline type. On the other hand, there are rocks which, taken by themselves, must be assigned to the calcic division. Augite-andesites, for example, are well known, especially in parts of western Argyllshire, in Arran and the Cumbraes, and in the outlying districts of the north of Ireland, Anglesey and the northeast of England. That these rocks have arisen as products of a subsidiary differentiation, we have in some cases almost ocular demonstration; for in Arran and elsewhere augite-andesites are found in remarkably intimate association with complementary types, often pitchstones of alkaline composition.

Even from so brief and imperfect a sketch we may, I think, draw some conclusions which have a wider application. This province exemplifies at once the two main tectonic types, and also comprises representatives of the two great branches of igneous rocks. Those rocks which are related to broad movements of Atlantic type indicate a parent magma of decided, though not strongly marked, alkaline nature; while those related to local movements of Pacific type clearly come from a calcic magma. There are some facts which suggest that the rocks tend to become more alkaline as we recede from the chief centers of activity, and this suggestion applies to some calcic as well as alkaline groups of rocks. Finally, it appears that the relative simplicity of arrangement was disturbed at a late stage by the effects of subsidiary differentiation, the province tending then to break up into districts related to new centers. Operating upon an initial magma not very strongly characterized, this later differentiation has even given rise to aberrant rock-types which overstep the petrographical boundary line between the two branches.

PETROGENESIS AND SYSTEMATIC PETROGRAPHY

From such considerations as I have hastily passed in review, it is evident that a survey of igneous rocks as they actually occur in the field leads to a conception of their mutual relationships very different from that embodied in the current schemes of systematic petrography. It may be of some interest, in conclusion, to expand this remark a little farther, although I am sensible that in so doing I lay myself open to the charge of vain speculation.

From the petrogenetic point of view, the most fundamental division among igneous rocks is that between the alkaline and calcic branches. This result, independently arrived at on petrographical grounds by several authorities, seems to be firmly established by the broad distribution of the two branches in different regions of the globe. But, if this argument be admitted, it follows that the next step in a natural grouping of igneous rocks should be suggested by a comparison of the characteristics of the various provinces into which the great regions divide. Many of these provinces have now been partly studied, and their special characteristics can often be expressed in concise terms: *e. g.*, among alkaline rocks the relative proportion of potash to soda may be a characteristic common to a whole province. More precisely, by averaging the chemical analyses of the chief rock-types, weighted according to

their relative abundance, it is possible to calculate approximately the composition of the parent-magma of a province. Noting that nearly identical assemblages of rocks sometimes occur in widely separate provinces and at different geological periods, we have some reason for expecting that the provincial parent-magmas may ultimately be reduced to a limited number of types. Whether these types will be sufficiently definite to serve as a basis of classification it is too early to say.

For the sake of argument, I have taken chemical composition as the criterion. It is certain, however, that a rock-magma consists, not of free oxides, but mainly of silicate-compounds, and the variation produced by magmatic differentiation is a variation in the relative proportions of such compounds. The characteristics common to a set of cognate rock-types will, therefore, be more properly expressed in mineralogical than in chemical terms. If, to fix ideas, we take as representative of a province its principal plutonic series, we shall often find that some particular mineral or some special association of minerals stands out as a distinctive feature. For instance, in the charnockite-norite series of southern India the characteristic ferromagnesian mineral is hypersthene; in the granite-gabbro series of the British Tertiary it is augite; and in the granite-diorite series, which predominates among the "newer granites" of the Scottish Highlands, hornblende and biotite. These three sets of rocks, all of calcic facies, are easily distinguishable in isolated specimens.

Each such rock-series embraces types ranging from acid to ultrabasic. This variation is ascribed to a later differentiation of the parent-magma of the province, and, therefore, in an arrangement based on genetic principles, it will find expression, not in the main divisions of the scheme, but in the subdivisions. Here is an essential difference between an ideal petrogenetic classification and the petrographical systems which are, or have been, in use. If we are content to limit our study of igneous rocks to specimens in a museum, the distinction of acid, neutral, basic and ultrabasic may seem to be of first importance. It has, in fact, been employed for the primary divisions in some formal schemes, *e. g.*, in that put forward by Löwinson-Lessing. In a less crude system, like that of Rosenbusch, this element disappears, but the underlying idea still remains. There is a division into families, such as the granite-family and the gabbro-family, but the term, in so far as it implies blood relationship, is a misnomer. The augite-granite of Mull is evidently more closely related to its associated gabbro than it is, say, to the biotite-granite of Peterhead or the hypersthene-granite of Madras.

The differentiation which evolves a varied series of plutonic rocks from a common parent-magma is clearly not of the same kind as that which gave rise to the parent-magma itself. It appears that the external mechanical element is here a less important factor, and the variation set up is, therefore, more closely in accordance with the uninterrupted course of crystallization. This is clearly indicated when we compare the order of intrusion of the several rocks of the series with the order of crystallization of their constituent minerals. The history of the series is in a sense epitomized in the history of each individual type, corresponding in both cases with continued fall of temperature and progressive change in the composition of the residual magma. In a large number of rocks, more particularly those of complex constitution, the order of crystallization follows Rosenbusch's empirical law of decreasing

basicity, and the plutonic intrusions then begin with the most basic type and end with the most acid. I mention this only to point out that, while the larger divisions of our ideal classification will have a certain geographical and tectonic significance, the subdivisions will show a certain correspondence with the sequence in time of the various cognate rock-types.

To pursue the subject farther would serve no useful purpose. It is clear that, if a natural—by which I mean a genetic—classification of igneous rocks is ever to become a reality, much work must first be done, both in the field and in the laboratory, each petrographical province being studied from the definite standpoint of the evolution of its rock-types from one parent stock. Such researches as those of Brögger in the Christiania province may serve as a model. It would be rash to venture at present more than the most general forecast of the lines which future developments may follow; but I think it calls for no less hardihood to set limits to what may ultimately be possible in this direction. There are those who would have us abandon in despair all endeavor to place petrography upon a genetic basis, and fall back upon a rigid arbitrary system as a final solution of the difficulty. This would be to renounce forever the claim of this branch of geology to rank as a rational science. I have said enough to show that I am one of those who take a more hopeful view of the future of petrology, confidently expecting it to show, like the past, a record of continued progress.

ALFRED HARKER

LETTER TO THE SECRETARY OF AGRICULTURE DISMISSING THE CHARGES AGAINST OFFICERS OF THE BUREAU OF CHEMISTRY

I RETURN herewith the papers which you have submitted to me in the matter of the report of the Committee on Personnel of the Department of Agriculture, in which, after summarizing the evidence adduced before them, they recommended that Dr. H. H. Rusby, pharmacognosist in the Bureau of Chemistry, be dismissed from the service; that Dr. L. F. Kebler, chief of the drug laboratory in the Bureau of Chemistry, be reduced from his present position, and Dr. H. W. Wiley, chief of the Bureau of Chemistry, and Dr. W. D. Bigelow, assistant chief of the bureau, be given an opportunity to resign from the positions which they now hold in the Bureau of Chemistry, on account of the irregularities in the appointment of Dr. H. H. Rusby.

The facts shown by the papers, stated shortly, are as follows:

Dr. Rusby lived in New York, and was employed as a scientific expert in the Bureau of Chemistry to examine importation of drugs, under an agreement by which he received $20 a day for laboratory work and $50 a day for attendance in court.

On May 24, 1909, the Attorney-General advised the Secretary of Agriculture that, under the act of March 4, 1907 (34 Stat. 1289), no classified scientific investigator should receive a salary to exceed $9 a day. On May 29, 1909, an order was issued putting him on the roll at a salary of $9 a day when actually employed. Dr. Rusby objected to this, and applied to Dr. Kebler, chief of the drug laboratory, to secure a different arrangement. The matter seems to have been held in abeyance for some time. Finally, as a result of conference between Dr. Kebler, Dr. Bigelow and Dr. Wiley with respect to the request of Dr. Rusby for an increased compensation, Dr. Wiley said he would submit to you for your approval an appointment of Dr. Rusby at a salary at the rate of $2,000 per annum on the miscellaneous roll. Dr. Bigelow then wrote to Dr. Rusby, under date of January 2, 1910, as follows:

> Dr. Kebler and I took the matter up with Dr. Wiley to-day, and he said he would approve it if we had on record an understanding with you, so we could not be held responsible for your receiving

an annual salary and not devoting your whole time to the bureau. I told him that if you were given an appointment at the rate of $170 a month, you would agree not to receive more than $20 a day for time actually employed. By that I mean the usual official day of seven and one half hours. This would be equivalent to eight and one half days a month on the average. I told him that if it happened that your work for the department amounted on the average to less time than that you would ask for leave of absence for sufficient time to bring it to that basis.

Dr. Rusby answered this letter and questioned what was meant by it. He said he did not understand Bigelow's letter clearly and supposed that if he did not earn the entire salary, he would not expect to receive any more than was earned.

Meantime, on February 6, Dr. Wiley submitted to you an appointment of Dr. Rusby at a salary at the rate of $1,600 per annum on the miscellaneous roll. He made the reduction after examining the records and finding the amount of work done by Dr. Rusby during the preceding two years. You approved this appointment.

After the appointment Dr. Bigelow wrote Dr. Rusby that he thought the present arrangement was better than the former arrangement when he was receiving $20 per day for laboratory work, and $50 a day for court work, because, he said, "you are now assured of getting a certain amount each month, irrespective of the time spent, and you can still so plan your work as to interfere with your regular duties to a minimum extent."

This did not satisfy Dr. Rusby, and he sought further information in a letter dated March 3, 1911, as follows:

> Kindly recall that on my side the basis of compensation is not less than $20 per day. At that rate only eighty days' work per year are provided for, and that is not time enough to satisfactorily perform more than the current port work here, leaving no time for examination of interstate samples, especially microscopical examinations, or for attendance at court. For every day at court, on the average, one day of preparation is required.
>
> The above facts lead to the inquiry, would not the salary named compel me to either do very much more than eighty days' work per year or otherwise fail to do the necessary amount of work in a satisfactory manner?

On March 4 Dr. Kebler wrote to Dr. Rusby, stating among other things the following:

> Personally I am of the opinion that your new appointment is much better than the old. Under this appointment you can do as little as one day's work per month, and you get your salary. On the other hand, if you work five or ten days, your salary would be the same per month. It seems to me that you have the matter largely in your own hands. I am satisfied that if you do not accept the new appointment nothing more can be done and your services, so far as our work is concerned, can no longer be utilized materially in the future.

On March 6 Dr. Rusby wrote to Dr. Kebler saying that he had decided to accept the appointment.

The nub of the charge by the Personnel Board was that Dr. Wiley, Dr. Kebler Dr. Bigelow and Dr. Rusby in effect conspired to put on the record a contract for a general employment of Dr. Rusby's services for $1,600 a year, but actually and secretly made a contract with him by which he was only to do enough work during the year for the $1,600 to secure him a compensation of $20 a day, and that this was done in deliberate and defiant violation of the law as interpreted by the Attorney-General in the opinion already referred to, in which he held that congress had limited the compensation of experts to $9 a day.

After you submitted to me the report of the Personnel Board, I asked the Attorney General to examine it and give me his opinion in respect to the matter, because it concerned the violation of the law as interpreted by him in one of his opinions. He did so, and advised me that the recommendations of the Personnel Board ought to be carried out. In connection with his recommendations he invited attention to a clause in the Act of Congress approved March 15, 1898 (30 Stat. L, 316), still in force, that enjoins upon the head of each department the duty of exacting from the employees in that department who are

under an annual salary labor amounting to seven hours every day but a holiday.

An examination of the records satisfied me that the questions had not been presented to the persons involved in such a way as to enable them to make full defence. They had only been called as witnesses and cross-examined without a full understanding that they were under trial which might involve their dismissal. Accordingly, I directed you to submit the whole record, together with the opinion of the Attorney-General, to each one of the persons charged, and invite from him an answer. These answers were filed in due course, and are quite full in detail. The answer of Dr. Wiley specifically denies that he ever saw the correspondence between Dr. Kebler and Dr. Rusby, or that he ever consciously entered into an arrangement by which Dr. Rusby was in effect to receive compensation at a rate in excess of that prescribed by the statute as interpreted by the Attorney-General. The truth is, it appears from the answers of Dr. Wiley, Dr. Kebler and Dr. Bigelow, that there had been a good many precedents in the department which seemed to justify the employment of Dr. Rusby at an annual salary, when it was not expected that his entire time would be taken up. This was the case with respect to the employment of what was known as the Remsen Board. That board was created by order of President Roosevelt for the very important purpose of enabling the Secretary of Agriculture to have reviewed the decisions of the Bureau of Chemistry in cases where those decisions involved disputed technical questions, and would, if sustained, have destroyed valuable and profitable business theretofore regarded as lawful. In such cases it was deemed wise not to allow the destruction of what would be otherwise lawful property and business on the decision of only one expert or the head of the bureau. Accordingly, the Remsen Board was created, and is composed of experts, all of whom were known to be engaged in other professional work than that of the reviewing board. Dr. Remsen, the head of the board, occupies an important position in Johns Hopkins University, and that is his principal occupation. Another member, Dr. Russell Chittenden, of the Sheffield Scientific School, is dean of that school, and that is his chief vocation. Hence, the employment of the Remsen Board at the rate of $2,000 a year for each member necessarily involved the proposition that such an annual salary might lawfully be paid without requiring labor of seven hours a day from each person so employed. This the Attorney-General in his opinion intimates is contrary to the statute, but in the Agricultural Department it was not thought to be the case. Solicitor McCabe, to whom I referred the question of precedents made in the case, replied that in the practise of the department the clause in the appropriation act of March 15, 1898, had been held to have no application to the employment of experts outside of Washington.

It is necessary fully to understand this difference between the attitude of the department toward an employment at an annual salary of this kind and the opinion of the Attorney-General in this matter, because if Dr. Wiley and his associates had understoood that the $1,600 annual salary required them to exact from Dr. Rusby seven hours a day for all the work days of the year, then of course his employment must have been known by them to be illegal and under the circumstances to be only a cover for a different contract of employment; but if they understood, as seems to have been the case generally in the agricultural department, that such an employment at an annual salary might be entered into with experts of this kind, and only subject the experts to an obligation to work for the department whenever called upon, with the understanding that they had some other vocation to which their chief attention was given, it clearly reconciled the action of Dr. Wiley with a desire to comply with the law. The recommendation of the Attorney-General given to me was upon only part of the evidence, and hence his judgment was different, doubtless from what it would have been if

he had had the whole record before him, as I have now. It seems fairly clear that Dr. Wiley, after an examination of the records concluded that the employment of Dr. Rusby at $9 a day for laboratory work and $50 a day for court work would amount to $1,600 a year if the department called on him whenever they needed him, and that it was this arrangement to which you consented. In Dr. Kebler's anxiety to induce Dr. Rusby to accept the new terms of employment he certainly betrayed a willingness to construe the contract of employment of Dr. Rusby at $1,600 a year in one way to reconcile it with the law, and in another way to satisfy Dr. Rusby in his wish to secure $20 a day, and I think he ought to be reprimanded for his disingenuous conduct in writing such letters as he did. He said that he did not intend to violate the statute as interpreted by the Attorney-General, and indeed that he did not know exactly what the ruling was; but whether he did or not, the language of his letters does not have a commendable tone and suggests a willingness to resort to evasion that calls for official reproof.

In respect to Dr. Rusby I do not find that he was advised at all as to the legal difficulty, and that he was only seeking for additional compensation which he thought to be adequate.

The truth is, the limitations upon bureau chiefs and heads of departments to exact per diem compensations for the employment of experts in such cases as this is a doubtful legislative policy. Here is the pure food act, which it is of the highest importance to enforce and in respect to which the interests opposed to its enforcement are likely to have all the money at their command needed to secure the most effective expert evidence. The government ought not to be at a disadvantage in this regard, and one can not withhold one's sympathy with an earnest effort by Dr. Wiley to pay proper compensation and secure expert assistance in the enforcement of so important a statute, certainly in the beginning when the questions arising under it are of capital importance to the public.

If this were a knowing, wilful, deliberate effort to evade the statute as construed by the Attorney General, accompanied by a scheme to conceal the evasion and violation, I should think the punishment recommended by the personnel board, and concurred in by the Attorney-General, was none too great; but an examination of the whole case satisfies me that a different construction ought to be put upon what was done; that the evidence does not show that Dr. Wiley was a party to the correspondence or the letters upon which the chief charge is founded, and that his action in the matter was only in accord with previous precedents in the department which justified him in doing what he did.

With respect to the other persons charged, I find an overzeal in Dr. Kebler and Dr. Bigelow which prompted a disingenuous method of squaring Dr. Rusby's desire for what he thought was adequate compensation with the contract which you and Dr. Wiley were willing to make with him and that for this Dr. Kebler and Dr. Bigelow should be reprimanded by you. So far as Dr. Rusby is concerned, with respect to this particular contract, I do not find him at fault. For purposes of punishment or dismissal, I can not charge him with knowledge of the legal difficulties involved in his employment.

I examined the record in this case a number of weeks ago and reached the conclusion which I have stated here; but meantime, a committee of the House of Representatives deemed it proper to institute an investigation into the Department of Agriculture, and especially into the Bureau of Chemistry and its relation to the department generally.

It seemed to me under these conditions that perhaps it was wiser for me to delay until the investigation was completed and the report of the committee made. The committee has not made a report, although I believe the evidence has been substantially closed, and will not do so until the next session of congress. Further consideration satisfies me that there

are very much broader questions involved in the investigation and the evidence there brought out than in the present charge which is narrower and definite and can now be properly disposed of. The broader issues raised by the investigation, which have a much weightier relation than this one to the general efficiency of the department, may require much more radical action than the question I have here considered and decided.

There is another charge against Dr. Rusby for securing the appointment on the common laborers rolls, of a physician and expert, whom he could use to do his work at a very small stipend when he himself was called away in other employment. I regret to say that the arrangement which Dr. Rusby thus made is not especially creditable to him and shakes in some degree one's confidence in his avowed wish to make personal pecuniary sacrifice in the public interest for the enforcement of the pure food law. But Dr. Rusby's position as an expert of high standing is such that I do not think that any more than this expression of opinion should be imposed as penalty. My information is that the government needs his services and that he has already rendered valuable aid. The error referred to, committed by him, does not call for further action or remark.

You will communicate the result to the Personnel Board, and also to the persons charged.

Sincerely yours,

WILLIAM H. TAFT

PROFESSOR JOSIAH KEEP

PROFESSOR KEEP, whose death, on July 27 last, at Pacific Grove, California, was recently announced, was born in Paxton, Mass., in 1849, and was a graduate of Leicester Academy and Amherst College (1874), taking his Master's degree as a post-graduate student in 1877. In that year he married Amelia Caroline Holman, of Leicester, Mass., and went to California. There he taught in the Golden Gate Academy and the Alameda High School, being principal of the latter from 1881 to 1885. In 1885 he became Professor of the Natural Sciences in Mills College, which, from small beginnings as a private seminary for girls, has through the efforts and generosity of its founders developed into a well-equipped and charmingly situated college, the Wellesley of the Pacific Coast.

Here Professor Keep found his life work as teacher and coadjutor with the still surviving founder, Mrs. Mills, and saw the branches of science originally confided to him alone, by degree represented in the teaching force by a number of competent instructors, while he retained for himself the subjects of geology and astronomy.

With the wide general knowledge required by his field of work, it was of course impossible for him to be a specialist in any, but his deep interest had been aroused in the study of the mollusca in which the Pacific Coast is so rich. Between 1881 and 1911 he published a series of what might be called primers of west-coast shells, illustrated with figures, enabling the beginner to gain a preliminary knowledge of the attractive shells of California. To these little books we may fairly ascribe much of the wide-spread interest which is to-day found among Californians and which by the cooperation of amateurs with specialists, has immensely increased our knowledge of the Pacific coast fauna.

The last of these manuals was published only shortly before his death. Professor Keep was one of the founders of the Chautauqua Assembly which meets at Pacific Grove, and frequently lectured to its classes on his favorite subject. He was also one of the most earnest supporters of the Museum and Library at Pacific Grove.

Modest, courteous, indefatigable and enthusiastic, he was primarily a teacher and organizer; beloved by his classes and appreciated by those reached through his books and so led to the study of nature. In his unassuming way he has done a good work and found his reward in doing it. He leaves a widow, son and daughter to mourn his loss.

WM. H. DALL

A NEW NATIONAL MATHEMATICAL SOCIETY

Each of the five leading mathematical countries of the world—Germany, France, Italy, England and America—has a flourishing national mathematical society. In England and in Italy these societies still bear local names, while in America the name was changed from New York to American several years after the organization of the society.

Although the oldest of these societies, the London Mathematical Society, was organized a little less than half a century ago, they have developed at a marvelous rate during the last few decades and they play a prominent rôle in the present mathematical activity. At least two of them, the German and the Italian, are rapidly assuming an international character. In fact, considerably more than a hundred Americans are now members of the Italian society, while the German society has about eighty such members.

A Spanish Mathematical Society was organized at the University of Madrid during a session held on the fifth day of last April. Whether this new national society will assume a prominent place among those named above, remains to be seen. It has comprehensive plans with a view to uniting the Spanish mathematicians, and its development will be watched with unusual interest by Americans, since the Spanish language is used so extensively on our continent.

During the month following its organization the Spanish Mathematical Society began the publication of a monthly periodical bearing the name *Revista de la Sociedad Matemática Española.* Judging from the title page, it is to be very comprehensive, including articles on analysis, geometry, mechanics, astronomy, mathematical physics, geodesy, history, pedagogy, etc. The material appears under seven sectional headings bearing the following names: biography, doctrine, bibliography, news, vocabulary, intermedium, problems.

The society aims to publish translations of important foreign publications and to furnish these to its members at cost or even at a lower price. It also undertakes to look up references for its members and to furnish them with translations of journal articles at cost. The administrative office of the society is at 51 San Bernardo, Madrid, Spain, and the comprehensive plans of organization include a division of its members into nine different classes.

The first two numbers of the *Revista* have appeared and are very creditable in view of the general aims of the society. They contain 40 and 36 pages, respectively. The articles are brief and elementary, and comparatively few references are given. One could scarcely expect much in the way of profound scholarship in the early numbers of such a journal, as its main function is to awaken a mathematical interest and to reach many whom it can lead to higher planes and unite into a strong force.

Not all scientific men realize the urgent demands for wise labors in mathematical fields. In a recent number of the *Archiv der Mathematik und Physik,* volume 18, page 175, Professor Study makes the following observations: "As far as our geometrical production has any claims on earnest appreciation it is preponderantly careless work (Raubban). The success of Steiner and others with more or less natural talents seems to have aided to create a method, which is convenient, for both the author and the reviewer, of arriving at a verdict; according to this method only the *main facts* are considered in geometry, while precision is not regarded as a main fact." Professor Study goes on to point out that a great part of advanced geometry is now in the state of an undigested mass, and that it will require much additional work before all the matter which appears in Bianchi's classic "Lezioni di Geometria Differenziale" can be presented in a satisfactory manner.

While a considerable part of mathematics demands a re-working from the standpoint of precision, the numerous new fields that have been opened call continually for workers who are properly equipped. The increasing number of mathematical investigators calls for increasing supervision and direction, and

these can be most effectively furnished by mathematical societies. The new Spanish society has an unusually large amount of virgin soil, and the very rapid recent mathematical advances of Italy may inspire the hope that "nascitur non fit" may be applicable to this new society, and that it may have a healthy and rapid growth.

G. A. MILLER

AGRICULTURAL RESEARCH IN GREAT BRITAIN[1]

THE British Board of Agriculture and Fisheries has been in communication with the Development Commissioners with a view to the formulation of a scheme for the promotion of agricultural research and local investigations in England and Wales, and the treasury, on the recommendation of the commissioners, has sanctioned the allocation of funds to be distributed by the board in accordance with the general principles set out below. The total maximum sum which will be expended when the scheme is in full operation will be about £50,000 per annum.

The scheme provides for: (1) A system of agricultural research which will secure for each group of the problems affecting rural industry a share of attention roughly proportional to its economic importance. (2) The concentration of the scientific work on each group at one institution or at institutions working in combination. (3) Grants for special investigations for which provision may not otherwise be made. (4) The grant of scholarships with a view to the increase of the number of men fully qualified to undertake agricultural research. (5) The carrying out of investigations into problems of local importance, especially those involving the application of modern research to local practise, and the provision of scientific advice for farmers on important technical questions.

In making arrangements for the separate investigation, as far as possible, of each group of allied subjects the commissioners and the board have been impressed with the importance of securing continuity in work which is necessarily of considerable duration, and at the same time of providing staffs of specialists and experts who will be permanently engaged on work arising from the investigation of the same group of problems. By this means concentration and economy of effort will be better secured than it would be if a number of institutions were dealing at the same time with the same group of problems.

It is neither desirable nor possible to prevent all overlapping or duplication of work, but it is obviously necessary to proceed on a plan by which research work subsidized from public funds will not be unnecessarily duplicated. It is also desirable to arrange that each problem shall be undertaken by the institution best fitted to deal with it, and usually by the institution which has specially devoted its attention to problems of an allied nature. It is also important to avoid the giving of undue attention to one part of the field of agricultural research, to the exclusion of other parts which are of equal scientific and economic importance.

With these considerations in view, it has been arranged that grants should be made for research in the following groups of subjects: (1) plant physiology; (2) plant pathology and mycology; (3) plant breeding; (4) fruit growing, including the practical treatment of plant diseases; (5) plant nutrition and soil problems; (6) animal nutrition; (7) animal breeding; (8) animal pathology; (9) dairying; (10) agricultural zoology; (11) economics of agriculture.

[1] From the London *Times*.

THE AMERICAN MINING CONGRESS

THE fourteenth annual session of the American Mining Congress will be held at the Hotel La Salle, Chicago, Ill., October 24, 25, 26, 27 and 28. The original intention was to have the convention September 26 to 29. President Taft, however, found it would be impossible for him to attend and there arose the possibility that neither Secretary Fisher nor Director Holmes, of the Bureau of Mines, would reach Chicago by that date. The Alaska branch of the congress asked for a

postponement that they might send to the meeting a strong and representative delegation.

President Taft now heads the list of speakers and will address the congress on October 28, on the last day of the convention. Thus given an opportunity to obtain a general idea of the problem confronting the coal, metal and mining men from the speakers who have preceded him, he will be enabled to clearly outline the views of the administration on the various points at issue. The first public statement of the conclusions reached by Secretary Fisher as a result of his Alaskan trip will probably be made at this meeting. Director Holmes, of the Bureau of Mines, will deliver an illustrated address on "Coal Problems." Martin D. Foster, chairman of the house committee on mines and mining, will tell of the "Relation of Congress to the Mining Industry." President B. F. Bush, of the Missouri Pacific Railroad, will present a statement containing revelations of the present conditions of the coal industry, which will be a surprise even to many coal operators.

Governors Spry, of Utah, Carey, of Wyoming, Hawley, of Idaho, and Sloan, of Arizona, supported by a number of other western executives, will lead the discussions of the "Public Lands Questions of the West." They will come to the convention supported by strong contingents of delegates from west of the Mississippi and their views will be defined in no uncertain terms.

In addition to taking up the questions of policy for the opening up of Alaska and the public lands of the west, the general problems of the bituminous coal mining industry as intensified by the demand for better protection to miners and the conservation of fuel resources, will be another of the important issues considered. Of equal interest will be the discussions concerning workmen's compensation for the victims of mining accidents; the prevention of mining accidents; the prevention of waste of the natural resources and the conservation of the energy which now contributes to coal production.

HONORARY DEGREES AT THE UNIVERSITY OF ST. ANDREWS

The senatus academicus of the University of St. Andrews has resolved to confer a large number of honorary degrees at the graduation ceremonial to be held in connection with the celebration in September of the 500th anniversary of the foundation of the university. The doctorate of laws will be conferred on the following men of science:

Allbutt, Sir Thomas Clifford, Regius professor of physic, University of Cambridge.

Barlow, Sir Thomas (president and delegate, Royal College of Physicians, London).

Berry, George Andreas, hon. surgical oculist to H.M. in Scotland (delegate, Royal College of Surgeons, Edinburgh).

Borgman, Ivan Ivan, professor of physics (delegate, Imperial University of St. Petersburg).

Bramwell, Byrom, president Royal College of Physicians, Edinburgh (delegate, Royal College of Physicians, Edinburgh).

Brown, Alexander Crum, former professor of chemistry, Edinburgh University (delegate, Royal Society of Edinburgh).

Burbury, Samuel Hawksley, F.R.S., London.

Cameron, Sir Hector Clare, professor of clinical surgery in the University of Glasgow.

Caullery, Maurice Jules Gaston Corneille, professeur de la chaire d'evolution des êtres organisés (delegate, University of Paris).

Gotch, Francis, F.R.S., Waynflete professor of physiology, University of Oxford.

Graff von Pancsova, Ludwig B., professor of zoology (delegate, University of Graz).

Holst, Peter Fredrik, professor of pathology, University of Christiania (delegate, University of Christiania).

Horne, John, F.R.S., director of Geological Survey for Scotland.

Keen, William Williams, professor of surgery, Jefferson Medical College, Philadelphia.

Lagerheim, Nils Gustaf, professor of botany, University of Stockholm (delegate, University of Stockholm).

Lamb, Horace, F.R.S., professor of mathematics, University of Manchester.

Larmor, Sir Joseph, F.R.S., Lucasian professor of mathematics, University of Cambridge, secretary of the Royal Society (delegate, Royal Society).

Meldola, Raphael, F.R.S., professor of chemistry in Finsbury Technical College (City and Guilds of London Institute).

Minot, Charles Sedgwick, professor of histology and human embryology, Harvard Medical School, Boston.

Mittag-Leffler, Gosta, professor of mathematics, University of Stockholm, Djursholm u. Stockholm, Rosenbad, 2.

Nathorst, Alfred Gabriel, Intendent Naturhistoriska Riksmuseum (plant-paleontological department), Stockholm (delegate, Royal Swedish Academy of Science, Stockholm).

Nijland, Albert Antonie, professor of astronomy, University of Utrecht (delegate, University of Utrecht).

Perkin, William Henry, F.R.S., professor of chemistry, Victoria University of Manchester.

Pope, William Jackson, F.R.S., professor of chemistry, University of Cambridge.

Prain, Lt.-Col. David, F.R.S., director, Royal Botanic Gardens, Kew (delegate, Linnean Society, London).

Prince, Edward E., F.R.S., Dominion Commissioner of Fisheries, Ottawa, Canada.

Reddingius, Rutger Adolf, professor of pathological anatomy, rector, University of Gröningen (delegate, University of Gröningen).

Royce, Josiah, professor of history of philosophy, Harvard University.

Saundby, Robert, professor of medicine, University of Birmingham (president-elect British Medical Association).

Schäfer, Edward Albert, F.R.S., professor of physiology, Edinburgh University.

Schuster, Arthur, F.R.S., formerly professor of physics, University of Manchester.

Teall, Jethro Justinian Harris, director H.M. Geological Survey, London.

Thomson, Sir Joseph John, F.R.S., professor of physics, Cambridge.

Veit, Johann, professor of gynecology, University of Halle (delegate, University of Halle-Wittenberg).

Voigt, Woldemar, professor of physics, University of Göttingen.

Watts, William Whitehead, F.R.S., professor of geology, Imperial College of Science and Technology, South Kensington (president and delegate, Geological Society of London).

Woodward, Arthur Smith, F.R.S., keeper geological department, British Museum.

SCIENTIFIC NOTES AND NEWS

WE regret to record the death of Dr. Thomas Dwight, Parkman professor of anatomy in the Harvard Medical School.

DR. DAVID STARR JORDAN, president of Stanford University, who is at present in Japan, has been decorated by the Japanese emperor.

DR. EDUARD SUESS, emeritus professor of geology in the University of Vienna, who has celebrated his eightieth birthday, has retired from the presidency of the Vienna Academy of Sciences.

DR. GOTTLIEB HABERLANDT, professor of botany in the University of Berlin, has been elected a member of the Berlin Academy of Sciences.

MR. WM. PAUL GERHARD, of New York, has been awarded the honorary degree of doctor of engineering by the Technical Institute of Darmstadt, in recognition of his services to public health and sanitation.

DR. SHIGÉO YAMANOUCHI, professor of botany in Tokyo Teachers' College (now in the University of Chicago), received in July from the Japanese government the honorary degree of "Rigakuhakushi" (doctor of science).

PROFESSOR GAETANO LANZA, head of the department of mechanical engineering at the Massachusetts Institute of Technology for the past twenty-seven years, has retired and is now with the Baldwin Locomotive Works.

DR. WILLIAM H. BROWN has resigned his position as research assistant in plant physiology at the Michigan Agricultural College to become plant physiologist of the Bureau of Science at Manila, P. I. He sailed from San Francisco for the latter point on September 6. Dr. R. P. Hibbard, of the Mississippi Agricultural Experiment Station, has been chosen as his successor.

DEAN MELVIN A. BRANNON, formerly of the College of Medicine at the University of North Dakota but now of the College of Liberal Arts at the same institution, will spend the year at the University of Chicago engaged in advanced research work in plant morphology with special reference to bryophytes and

pteridophytes. His work will have a particular bearing on certain problems in the study of plant life that are being worked out in North Dakota.

Professor Henry E. Crampton, of Columbia University and the American Museum of Natural History, is at present on leave of absence and is taking part in an expedition which has penetrated the interior of South America in search of zoological material.

Dr. J. George Adami, professor of pathology in McGill University, has gone to Europe to attend the Tuberculosis Conference in Rome.

Dr. P. G. Spinelli, professor of gynecology in the University of Naples, is making a study of hospitals in the United States.

Messrs. V. Kotchetkoff, of the department of agriculture, Moscow, and D. Roodzinski, director of the Selection Station of the Moscow Agricultural Institute, spent several days recently in a study of the work of the Bureau of Plant Industry and especially the work of the bureau farm at Arlington, Va., as an introduction to a six months' investigation of agricultural methods and conditions in the United States.

The Harvey Society has secured the following distinguished lecturers for the coming season: Professor W. B. Cannon, of Harvard Medical School; Professor R. H. Chittenden, of Yale University; Dr. Simon Flexner, of the Rockefeller Institute; Professor H. S. Jennings, of Johns Hopkins University; Professor Albrecht Kossel, of Heidelberg University; Dr. H. F. Osborn, of the American Museum of Natural History; Dr. J. J. Putnam, of Harvard Medical School; Professor T. W. Richards, of Harvard University; Professor W. T. Sedgwick, of the Massachusetts Institute of Technology; Dr. W. S. Thayer, of the Johns Hopkins Medical School, and Professor Verworn. The following lectures will be delivered during the month of October: "Local Specific Therapy of Infections," by Dr. Simon Flexner, on the 7th; "The Chemical Structure of the Cell," by Professor Albrecht Kossel, on the 14th; "Anesthesia," by Professor Verworn, on the 28th.

Mr. J. R. Mortimer, of Driffield, England, known for his work in prehistoric archeology, died on August 20, in his eighty-seventh year.

Dr. G. F. Blandford, formerly lecturer on psychological medicine at St. George's Hospital, London, and known for his work on insanity, has died at the age of eighty-two years.

Dr. Emanuel von Hibler, professor of pathological anatomy in the University of Innsbruck, has died from sepsis contracted in the *post-mortem* room.

Dr. Georges Dieulafoy, formerly professor of clinical medicine at the University of Paris, has died at the age of sixty-two years.

The death is also announced of Professor Swarts, of the University of Genth, known for his contributions to chemistry.

Dr. Franz Czermak has bequeathed a million crowns to the Vienna Academy of Sciences without restriction as to its use.

A settlement has been arrived at in regard to the question of the South Kensington site by the terms of which the Natural History Museum retains all the land allotted to it in 1899, and the boundary then agreed upon is not to be disturbed. The Science Museum will be proceeded with on the land to the north of the boundary of the Natural History Museum.

Nature reports that at the National Congress of Applied Chemistry, which is to be held at Turin from September 23 to 28, a general discussion will take place on the fiscal and customs practise in regard to the industrial use of alcohol, and Professor Miolati will give an experimental demonstration of the use of atmospheric nitrogen for industrial purposes.

It is stated in the *British Medical Journal* that the third Congress of the International Surgical Society will be held at Brussels at the end of the month. The members will be received on Monday evening, September 25,

by Dr. Lorthioir, president of the Belgian Surgical Society. The congress and the exhibition of fractures and surgical appliances will be opened at 9.30 on Tuesday morning, and immediately afterwards a discussion on pancreatitis will be opened by M. Michel. The afternoon session will be devoted to the discussion of the treatment of that disease, opened by MM. Körte and Giordano. In the evening the president of the International Society (Professor Lucas-Championnière) will hold a reception. Wednesday will be devoted to the surgery of the thorax, the introductory addresses being given by MM. Garrè, Gaudier, Girard, Lenormand and Ferguson. Thursday morning will be given up to demonstrations of fractures, and the afternoon to the discussion of pulmonary abscess and gangrene and bronchiectasis, introduced by MM. Van Stockum and Sauerbruch. Subjects for discussion on Friday are the surgical treatment of pulmonary tuberculosis and acute and chronic colitis. There will be a banquet on Thursday evening, and a gala performance at the Theater Royal on Friday evening.

THE Harpswell Laboratory was open during the season just closed from June 15 to September 11. During this time the following investigators carried on work there:

George A. Bates, professor of histology, Tufts Medical School, Boston.

Violet Dandridge, artist, U. S. National Museum, Washington.

Reuben J. Erickson, student, Knox College, Galesburg, Ill.

C. McLean Fraser, assistant, University of Iowa, Iowa City.

Abram T. Kerr, professor of anatomy, Cornell University, Ithaca.

Agnes R. Kerr, Ithaca.

Duncan S. Johnson, professor of botany, Johns Hopkins University, Baltimore.

J. S. Kingsley, professor of zoology, Tufts College, Tufts College, Mass.

Margaret Reed Lewis, Baltimore.

Warren H. Lewis, assistant professor of anatomy, Johns Hopkins University, Baltimore.

Herbert V. Neal, professor of zoology, Knox College, Galesburg.

Mary J. Rathbun, curator of invertebrates, U. S. National Museum, Washington.

Marian L. Shorey, professor of zoology, Milwaukee-Downer College, Milwaukee.

Leonard W. Williams, instructor in comparative anatomy, Harvard Medical School, Boston.

THE *Scottish Geographical Magazine* quotes the excursions to be made from October 23 to November 1, after the holding of the International Geographical Congress in Rome. Of these the first or northern excursion is to the lower valley of the Po and the Fore Alps. The starting-point is Ferrara, where the delta of the Po will be examined and a steamer journey on the river undertaken from Pontelagurasco to Mantua. Verona will then be visited, and the lakes of Garda and Iseo. The valley of the Serio will be traversed, special attention being paid to the development of industries here, and the use of water power. From Bergamo the lakes of Como and Maggiore will be crossed, thence the party will descend to Milan, where various scientific and industrial undertakings will be visited. On the way to Turin the town of Novara will be examined. The total expenses of this excursion will not exceed 380 Italian lire, and the objects of study will be physical and economic geography. Participants will be presented with a monograph of the delta of the river Po, with maps, especially prepared by Professor Mario Barrata, of the University of Pavia. The second excursion is to Naples, Palermo and the coasts of eastern Sicily and Calabria, and will be devoted to physical geography and vulcanology. The party is to meet at Naples, where a day will be devoted to the sights of the neighborhood, a choice having to be made between the three following: Vesuvius and Pompeii, the Phlegrean Fields or Capri. On the twenty-fourth of October the party will start by steamer for Palermo, traveling next day to Catania, where Mount Etna can be ascended or a tour made round its circumference. Thence the ruins of Messina and Reggio and the rebuilding of these towns will be examined. From Reggio excursions will be taken to the neighboring coastline to inspect the effects of the earthquake, and a return will

be made to Messina, where the steamer will be taken to Naples again. This excursion will not cost more than 358 lire. The third excursion is a variant of the preceding, but gives more time to Naples and its vicinity. It allows three days for Naples, and joins up with the other excursion at Catania. The cost will be about 366 lire. All excursionists are invited to visit the exhibition at Turin on November 1, and on the evening of that day the excursion will be regarded as closed.

UNIVERSITY AND EDUCATIONAL NEWS

The Japanese Minister of Education has announced that two new imperial universities will be opened. One will be at Sendai, on the eastern coast, and the other at Fukuoka, on the island of Kiushu.

Dr. Jack P. Montgomery, of the Mississippi Agriculture and Mining College, has been appointed adjunct professor of chemistry at the State University of Alabama.

Homer C. Washburn, B.S., Ph.C., has been appointed professor of pharmacy in the University of Colorado. He is a graduate of the scientific and pharmaceutical departments of the University of Michigan. For seven years he has been a member of the faculty of the University of Oklahoma and for the last six years dean of the School of Pharmacy.

Mr. W. A. Whitaker, Jr., of the department of chemistry, College of the City of New York, has accepted the associate professorship of metallurgy in the University of Kansas.

S. D. Magers, assistant professor of physiology in the Michigan State Normal College, Ypsilanti, succeeds Dr. E. R. Downing as professor of biology at the State Normal at Marquette, Mich.

Thomas L. Patterson, M.A., with the Gypsy Moth Parasite Laboratory during the past summer, has been elected professor of biological sciences at Highland Park College, Des Moines, Iowa.

Recent appointments at the State University of North Dakota are the naming of H. E. French, A.B. (Washington State, 1902), M.D. (Northwestern, 1907), and recently of the medical school of the University of South Dakota, as dean of the School of Medicine; Carl F. Raver, A.B. (Michigan), recently city bacteriologist for Oklahoma City, Oklahoma, as chemist in the State Public Health Laboratory; Roy E. Christie, A.B. (North Dakota, 1911), as assistant bacteriologist at the same place; Leon V. Parker, as bacteriologist in charge at the branch Public Health Laboratory at Minot, and Alfred Larson to fill a similar position in the branch laboratory at Bismarck.

DISCUSSION AND CORRESPONDENCE

THE GRAND CANYON OF THE COLORADO

On page 89 of Science, No. 864 (July 21, 1911), I observe a special article by H. H. Robinson entitled "The Single Cycle Development of the Grand Canyon of the Colorado."

During the summer and autumn of 1908 I spent several months in the Grand Canyon in the region about Shinumo Creek, making a study of the geology of the Shinumo quadrangle. The results of this study were presented at Yale University in the form of a Doctor's thesis, a part of which, dealing with the rocks of the Vishnu and Grand Canyon series, has been published in the *American Journal of Science* (May and June, 1910) under the title "Contributions to the Geology of the Grand Canyon." I have since returned twice to the region to extend the same study in the interest of the United States Geological Survey; the entire report on the geology of the Shinumo quadrangle is to be published at a future date as a Bulletin of the Geological Survey.

My observations in that region (recorded in the thesis, but not yet published) are entirely in accord with the conclusions of Davis and Robinson in regard to the dependence of the benches in the canyon upon the character of the strata.

The Shinumo quadrangle is a critical area for the study of the two greatest benches within the canyon, the Esplanade and the Tonto Platform, since it is there that the profile of the canyon wall changes from that which is characteristic of the Kaibab division to that which is characteristic of the Kanab. Eastward from Havasupai Point, a great promontory of the southern wall in the center of the quadrangle near Bass Camp, the scenery is that which is characteristic of the Kaibab division. This is the scenery that is familiar to most of the visitors at the Grand Canyon, from the views in the vicinity of El Tovar hotel. The walls are greatly dissected, particularly on the northern side of the canyon. Great amphitheaters run far back into the wall, filled with fantastic buttes and temples, and trenched by innumerable side gorges. The profile of the wall is especially distinctive; the edges of the Paleozoic strata descend rapidly through a series of cliffs, steep slopes, and narrow ledges to the Tonto Platform, 3,000 feet below the rim of the canyon; within the Tonto Platform is the Granite Gorge, at the bottom of which the river flows upon Archean rocks.

Turning westward from Havasupai Point, there is a striking change. Directly below, about 1,000 feet beneath the rim, a great flat-topped spur of red Supai sandstone runs far out into the canyon. Farther westward, more and more of these spurs appear, each capped with a similar platform which always lies upon the same layer of red sandstone. Gradually the platform widens and becomes a broad expanse of red rock, which is covered with patches of scanty soil and dotted with scrubby trees of juniper and pinyon. The buttes and temples disappear; the walls are much less dissected by side gorges and extend in solemn palisades. The cross-section of the canyon wall is more simple, consisting of a wide outer valley whose floor is the great red platform, and a narrow inner canyon, at the bottom of which is the river. This platform is named the Esplanade. The wall of the inner canyon is stupendous, the edges of the Tonto, Redwall, and Supai strata appearing almost as a single cliff, 3,000 feet in height. This type of scenery is characteristic of the entire canyon west of the Kaibab division.

Opposite Havasupai Point, in the central part of the quadrangle both platforms are present, separated vertically by 2,000 feet. It is therefore manifestly impossible that the two platforms represent one base-level of erosion.

The greater dissection of the walls in the Kaibab division is, of course, due to the greater altitude of the plateaus on either side of the canyon and the consequently greater rainfall that prevails.

The change in the profile of the wall to the westward can be clearly shown to depend upon certain variations in the thickness and character of the Paleozoic strata: Each ledge of the canyon wall is made by the wasting back of beds of weak strata from the summit of a resistant, cliff-making stratum below. The width of a ledge tends to increase with the thickness of the weak strata; it is also controlled by the relative thickness and strength of the overlying strata which defend the retreat of the wall above.

In the Kaibab division, the Bright Angel shale of the middle part of the Tonto group is uniformly weak and has wasted back rapidly from the summit of the basal Tapeats sandstone of the Tonto group, leaving the wide ledge known as the Tonto Platform. As the Bright Angel shale is traced westward into the Shinumo quadrangle, layers of resistant snuff-colored limestone begin to appear in the middle of the formation. These layers, known locally as the Snuffy limestone, gradually increase in thickness, making two delicate parallel cliffs which are a conspicuous feature in the interior of the canyon. The Snuffy limestone increases the resistance of the Bright Angel shales to erosion, so that they retreat more slowly and make a steeper slope; westward from Havasupai Point the Tonto Platform fades gradually and is no longer a prominent topographic feature in the canyon. At the same time, the Muav limestone of the upper part of the Tonto

group and the massive Redwall become gradually thicker to the northward and westward, and the inner canyon narrows as these strata become more and more effective in defending the retreat of the wall.

In the Kanab division, the Supai formation of the Aubrey group consists of weak red shales in the upper portion and resistant sandstones below. The shales waste back from the summit of the sandstones, leaving the Esplanade platform. In the western part of the quadrangle, where the Esplanade is fully developed, the thickness of the Supai shales is 550 feet; while that of the overlying massive white Coconino sandstone, which defends the retreat of the outer wall, is only 250 feet. Eastward from Havasupai Point, in the Kaibab division, the thickness of the Supai shale has decreased to 300 feet (becoming still thinner in the Bright Angel quadrangle to the eastward); while that of the Coconino sandstone has increased to 400 feet; the Esplanade fades to a narrow ledge in this part of the canyon.

L. F. Noble
Valyermo, California,
July 27, 1911

Draughts and Colds

To the Editor of Science: In reading the interesting and instructive communication by Mr. M. Mott-Smith in the August 4 number of Science, I was impressed by the closing paragraph, which follows:

> Though the above explanations are only a rehash of well-known principles, I hope they may be of some use. In return I wish some one would explain to me just what is the danger of the open window. Why is a little sneaking draught in the house a source of colds and grippe, while a high wind out of doors a pleasure and a benefit? This is a problem that has long puzzled me, but perhaps it is a foolish question.

This problem has doubtless puzzled a great many besides Mr. Mott-Smith, and is perhaps "a foolish question"; but why it should be a *foolish question* seems also a puzzle to a layman. The problem appears to involve the question, what is the pathology of a "bad cold"? The writer has propounded that question to several intelligent physicians, and its "foolishness" is attested by failure to elicit any attempt at a lucid reply.

The writer has been compelled to construct for himself what engineers would call a "working hypothesis" to cover this problem. and has even ventured to apply a quasi scientific name to fit the case, which is offered as a reply to Mr. Mott-Smith for what it may be worth, or otherwise, with all due diffidence and a proper sense of his temerity in trenching upon hallowed ground.

The answer thus boldly formulated as to the proximate cause of a "bad cold" is, *a disturbance of the thermo-neural equilibrium* of the surface of the body.

It is a matter of common experience that if a portion of the body, the head and neck, for instance, is exposed to a strong breeze while the remainder of the body is of normal or supernormal temperature, bad cold, grippe, etc., are pretty sure to result, while the "high wind out of doors," which envelops the whole body, has no such effect. One sitting in a country office on a very cold day, his feet thrust under a desk and his back to a glowing grate, shall after a while fall to sneezing, and if he is wise he will get up and stir around in order to restore this disturbed equilibrium in the temperature of the cutaneous nerves.

In this connection it may be said that the writer has found what is to him a completely satisfactory solution of the weighty question, how to deal with the long and oppressive summer heat in the southern states, to wit, the electric fan.

Nearly all persons are afraid to allow a fan to blow upon them while asleep; and indeed if the body is partially exposed to the action of the fan it is a dangerous practise. On the other hand it is the writer's constant practise to have a 16-inch fan blowing upon him all night in hot weather. When the temperature is very high the fan is run at top speed, and is graduated down for lower temperatures.

The point to be made is, that the fan is so located that it is in line with the sleeper's body, taking him from his feet to his head, and thus enveloping his entire body in the

volume of moving air. By this method of application of the fan there is no disturbance of the "thermo-neural" equilibrium of the body, and the writer has thus enjoyed the luxury of a cool bed without stint, in the hottest weather, without any evil effects.

It is the hope that others may profit by the above suggestion, that shall serve as an apology for this communication.

T. G. DABNEY

CLARKSDALE, MISS.,
August 13, 1911

BLANDING'S TURTLE

TO THE EDITOR OF SCIENCE: Mr. Howe's note in SCIENCE of September 1, reporting the capture of Blanding's turtle in Massachusetts, reminds me that I should make a note of the introduction of this turtle in Orange County, New York.

In 1909 I placed three pairs of Blanding's turtle (*Emys blandingi*) and three pairs of the map turtle (*Malacoclemmys geographica*) in Little Long Pond, near Southfields, Orange County. Some naturalist may discover them by and by, and it is desirable that a record be made of their introduction. Both species were collected in Erie County, Ohio.

C. H. TOWNSEND

NEW YORK AQUARIUM

QUOTATIONS

MEDICAL PRACTISE IN GREAT BRITAIN

As every one knows, the lines of work pursued by medical men vary greatly in different cases. Of all medical students a large proportion probably hope to develop into consultants or specialists, but sooner or later they learn that it is only to the few that a career of this kind is practically open. Even after a brilliant studentship success involves years of weary waiting, during which not even a bare living is made from practise; and, in fact, only those who have private means can afford, as a rule, to wait. Moreover, in every case the result is extremely uncertain, and one late outcome of legislation now in progress may be restriction of the field open to consultants and specialists of independent mind.

Despite, therefore, the apparent wealth of choice, the average newly qualified man has to elect between private general or family practise and an official career. Most men necessarily choose the former, if only for the reason that the number of posts in the public services is very limited. It is the more unfortunate, therefore, that the prospects of private practise are inferior to what they used to be. Complaints of lessened incomes and increased expenses began, indeed to come in a few years ago in such numbers that the subject was specially investigated by this *Journal,* and the results recorded in two articles on "The Financial Prospects of Medicine," which appeared in the *British Medical Journal* for June 12 and July 17, 1909. The net outcome of those articles was to prove that not only was the number of possible patients less, but each one of those that remained needed less medical attendance than formerly, especially for the zymotic diseases, which used to furnish so much work. In this connection must be mentioned the decline in the birth-rate, which not only affects the medical men of this generation, but must seriously influence the prospects of those who may succeed them. The counter-prescribing by chemists, the enormous sale of quack remedies, the growth of badly-paid club practise and of hospital abuse, have all taken away from medical men former paying patients. At the same time the State has from time to time thrown sundry unpaid duties on the shoulders of medical men.

The state has no conscience, but individual members of the public often seem, in their dealings with medical men, to have very little. The newly-qualified practitioner often thinks he is making a practise quickly, judging by the number of patients that come to his surgery, but too often he is disillusioned when he sends out his bills. If he press for payment before he is well established, the growth in his practise soon ceases, and, what is still more irritating, the very patients who had seemed to regard him as an angel of mercy not infrequently spread charges of incompetence or

neglect which, however fully disproved, invariably damages his practise.

The foregoing is a faithful account of the present drawbacks to private practise, and it must be repeated that the insurance legislation in view will not improve matters. Medical men who have gone in for contract practise at all have been able to afford to do so thanks to their possession also of ordinary practise among the same class of persons. But under the National Insurance Bill the whole of the working class will be swept into the contract practise net, and a smaller income will almost certainly result from the same amount of work despite the absence of bad debts. There may also be an extension upwards of the contract system, and a great deal even of the best class of private practise may thus be abolished. Another disadvantage which can not be ignored is that it will become impossible to build up a practise which can be sold in part or altogether. Indeed the mere introduction of the bill has already lessened the value of many practises as facultative assets.—*British Medical Journal.*

SCIENTIFIC BOOKS

Publications of the United States Naval Observatory. Second Series. Volume VI., with ten plates. Volume VII. Washington, Government Printing Office. 1911.

In accordance with the new policy of the Naval Observatory by which volumes are issued from time to time as material suitable in nature and quantity for simultaneous publication becomes available, we find volume VI. of the present two volumes made up as follows: (1) the data and results of all the observations made with the two equatorial telescopes, the 26-inch and the 12-inch, since the removal to the new site, or for the years 1894–1907; (2) Appendix I., a series of thirty-six astronomical papers by various members of the staff, embracing a determination of the mass of Titan, of the Solar Parallax from observations of Eros, and determinations of the orbits of a number of satellites, minor planets and comets; (3) Appendix II., a presentation of the observations of the transit of Mercury in 1894 made by more than twenty-three professional and amateur astronomers at as many stations in the United States from the Atlantic to the Pacific coast; (4) Appendix III., a complete and minutely described list of the publications of the observatory, from the beginning in 1845 till 1908.

This volume is of special interest to a wider public inasmuch as it contains, we believe, the first series of plates that have been generally distributed in illustration of the buildings and equipment of the new observatory. The frontispiece exhibits the dome and the attached, low, office building of the great equatorial telescope, making one harmonious structure, with white marble walls, standing apart on the spacious grounds. Probably this is the most gracefully formed astronomical dome in the country, if not in the world. Similar praise is to be given when we regard the plate which gives a view of the front of the main building. Here, again are fitness and beauty of proportion, a simplicty of outline and detail, which are an honor to the architect, the late Richard Morris Hunt. Besides these there are six plates which exhibit the construction and equipment of the 26-inch telescope and one which gives a general view of the 12-inch telescope.

This volume contains the work of a number of observers who have succeeded one another at the instruments in kaleidoscopic change. Indeed, one who has followed the annual pamphlet reports of the superintendent for several years past, is likely to have his head full of visions of a chain of observers marching and counter-marching around a circle of instruments, and to get the conviction that our National Observatory properly belongs in Alice's Wonderland. But here is a great mass of original astronomical data which appear to have been carefully derived, and the full value of which can only come out upon comparison with similar results from the different observatories of the world. If certain astronomers, of a type not unrepresented in this volume, would confine themselves to careful observation and leave the theorizing in newspaper and magazine articles

to others of less exuberant imagination, current astronomy might stand better with the intelligent public.

Of Appendix I. special mention may be made of the following determinations: of the mass of Titan by Professor Eichelberger from observations made by the late Professor Asaph Hall at the old observatory; of the orbits of Deimos and Phobos by Mr. J. C. Hammond, from the observations made by Mr. H. L. Rice, and of the solar parallax by Mr. C. W. Frederick, from observations of Eros made by Professor See. Then follows a long series of determinations of orbits for members of that swarm of tiny planets known as asteroids, which the astronomical student is inclined to believe were designed by an unkind Providence to furnish exercises in computation, but which may yet again develop some new and important interest. Here it is a pleasure to find that Mr. Matt Frederickson employs his ingenuity to derive a simple, explicit equation for a certain unknown in place of the implicit equation solved by previous computers by means of a series of approximations.

Volume VII. might be classed under Archeology, inasmuch as it is presentation of results of observations made on three old meridian instruments in the period 1846–1852. The work of reduction and preparation for publication has only recently been done, under the leadership of Professors Eichelberger and Littell, and seems to owe its completeness very largely to the faithful and intelligent service by Miss Etta M. Eaton. This is a work, both as to observation and computation, which hardly any but a government observatory would be willing to undertake. The exhiliration of spirits arising from such deferred labor is like that due to a campaign of elimination in the garret when a family moving is at hand. Yet unsuspected values may develop amongst its results; and the recent discovery of a large drift in space on the part of a star whose earliest known position is recorded in the old Gilliss Catalogue of 1850, also worked up at our national observatory, is a cheering incident to the patient laborers in this field.

A large part of the transit observations entering into Volume VII., from the earlier part of the period, were made by the eye and ear method, which is still in vogue for occasional observations. In connection with the summary of measures of accidental errors affecting the results in this catalogue, it is interesting to note here, what seems almost incredible to the beginner, that the employment of the electric chronograph reduced the accidental error by only slightly over six per cent. As is well known, the liability to accidental error in the case of the experienced observer is sensibly the same in both methods.

These two volumes are dignified and handsome products from the Government Printing Office. One important economic problem of the day is the condensed presentation of scientific and other data without detracting from a proper appearance and a form intelligible in reference. The present volumes are too expansive in some portions but show in other parts a commendable tendency to compactness.

ALBERT S. FLINT

Polar Exploration. By Dr. W. S. BRUCE. New York, Henry Holt & Co. 1911. Pp. 256.

The geographer, the scientist and the intelligent, enquiring reader will alike find this volume of the Home University Library most disappointing. The most that can be said in its favor is the pleasant, though often inconsequential manner in which the author puts forward descriptive phases of polar physics, in which he is personally interested. It is evidently written for the English market only. Entitled "Polar Exploration," it makes no mention of the polar work of Kane, Hayes, Rodgers, De Long, Greely, Lockwood or any other American, save to refer to "the boyish pole hunt," and a sea-sounding by Peary. There are desultory chapters on Plant and Animal Life, Meteorology and Magnetism, but no reference to the incomparable scientific observations of the International Polar Station by thirteen nations, published in forty quarto volumes.

A. W. GREELY

SPECIAL ARTICLES

RANDOM SEGREGATION VERSUS COUPLING IN MENDELIAN INHERITANCE

Mendel's law of inheritance rests on the assumption of random segregation of the factors for unit characters. The typical proportions for two or more characters, such as 9:3:3:1, etc., that characterize Mendelian inheritance, depend on an assumption of this kind. In recent years a number of cases have come to light in which when two or more characters are involved the proportions do not accord with Mendel's assumption of random segregation. The most notable cases of this sort are found in sex-limited inheritance in *Abraxas* and *Drosophila*, and in several breeds of poultry, in which a coupling between the factors for femaleness and one other factor must be assumed to take place, and in the case of peas where color and shape of pollen are involved. In addition to these cases Bateson and his collaborators (Punnett, DeVilmorin and Gregory) have recently published[1] a number of new ones.

In order to account for the results Bateson assumes not only coupling, but also repulsions in the germ cells. The facts appear to be exactly comparable to those that I have discovered in *Drosophila*, and since these results have led me to a very simple interpretation, I venture to contrast Bateson's hypothesis with the one that I have to offer.

The facts on which Bateson bases his interpretation may be briefly stated in his own words, namely: "that if A, a and B, b are two allelomorphic pairs subject to coupling and repulsion, the factors A and B will repel each other in the gametogenesis of the double heterozygote resulting from the union $Ab \times aB$, but will be coupled in the gametogenesis of the double heterozygote resulting from the union $AB \times ab$," and further, "We have as yet no probable surmise to offer as to the essential nature of this distinction, and all that can yet be said is that in these special cases the distribution of the characters in the heterozygote is affected by the distribution in the original pure parents." Bateson further points out that since "sex in the fowls acts as a repeller of at least three other factors, . . . some of them may be found able to take precedence of the others in such a way as to annul the present repulsion with subsequent coupling as a consequence."

In place of attractions, repulsions and orders of precedence, and the elaborate systems of coupling, I venture to suggest a comparatively simple explanation based on results of inheritance of eye color, body color, wing mutations and the sex factor for femaleness in *Drosophila*. If the materials that represent these factors are contained in the chromosomes, and if those factors that "couple" be near together in a linear series, then when the parental pairs (in the heterozygote) conjugate like regions will stand opposed. There is good evidence to support the view that during the strepsinema stage homologous chromosomes twist around each other, but when the chromosomes separate (split) the split is in a single plane, as maintained by Janssens. In consequence, the original materials will, for short distances, be more likely to fall on the same side of the split, while remoter regions will be as likely to fall on the same side as the last, as on the opposite side. In consequence, we find coupling in certain characters, and little or no evidence at all of coupling in other characters; the difference depending on the linear distance apart of the chromosomal materials that represent the factors. Such an explanation will account for all of the many phenomena that I have observed and will explain equally, I think, the other cases so far described. The results are a simple mechanical result of the location of the materials in the chromosomes, and of the method of union of homologous chromosomes, and the proportions that result are not so much the expression of a numerical system as of the relative location of the factors in the chromosomes. *Instead of random segregation in Mendel's sense we find "associations of factors" that are located near together in the chromosomes. Cytology furnishes the mechanism that the experimental evidence demands.*

T. H. Morgan

September 10, 1911.

[1] *Proc. Royal Soc.*, Vol. 84, 1911